AN INTRODUCTORY GUIDE TO ADAPTIVE MANAGEMENT

for Project Leaders and Participants

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Preface

Forest ecosystems are complex and dynamic. As a result, our understanding of ecosystems and our ability to predict how they will respond to management actions is limited. Together with changing social values, these knowledge gaps lead to uncertainty over how best to manage British Columbia's forests. Despite these uncertainties, forest managers must make decisions and implement plans. Adaptive management is a way for forest managers to proceed responsibly in the face of such uncertainty. It provides a sound alternative to either "charging ahead blindly" or "being paralysed by indecision", both of which can foreclose management options, and have social, economic and ecological impacts.

Adaptive management may be particularly valuable for testing, refining and improving the Forest Practices Code. Although the Code is based on the best available information and expertise, it requires forest managers and workers to implement many new, previously untested strategies. Managers are faced with questions such as: How do I implement the guidelines in a way that will meet management objectives? Which of several possible actions should I implement? There are also uncertainties about whether specific guidelines provide adequate protection for non-timber values, and whether others place unnecessarily tight constraints on timber harvesting. Adaptive management offers a powerful way for addressing these questions.

Adaptive management is a formal, systematic, and rigorous approach to learning from the outcomes of management actions, accommodating change and improving management. It involves synthesizing existing knowledge, exploring alternative actions and making explicit forecasts about their outcomes. Management actions and monitoring programs are carefully designed to generate reliable feedback and clarify the reasons underlying outcomes. Actions and objectives are then adjusted based on this feedback and improved understanding. In addition, decisions, actions and outcomes are carefully documented and communicated to others, so that knowledge gained through experience is passed on, rather than being lost when individuals move or leave the organisation.

Learning from experience is always valuable. A rigorous, deliberate approach to learning is appropriate whenever there is significant uncertainty about possible outcomes of alternative actions and where delaying action is either unnecessary or would have unacceptable ecological, economic or social impacts. To be effective, adaptive management requires a commitment to learn and adjust, adequate resources (e.g., for monitoring and data analysis), and access to necessary expertise. Be aware that complex, contentious problems will require more skill and expertise than simple problems and may take longer to resolve.

Adaptive management was developed in the 1970's by C.S. Holling and co-workers at the University of British Columbia and the International Institute for Applied Systems Analysis. Since then, it has been applied to a range of specific issues, including rehabilitation of salmon stocks in

the Columbia River Basin, management of acid rain, and water management in the Florida Everglades. Its application to forest management issues is now receiving increasing attention. For example, ten "Adaptive Management Areas" are now operating in the U.S. Pacific Northwest, the Clayoquot Sound Scientific Panel recommended an adaptive approach to managing Clayoquot Sound, and Alberta-Pacific Forest Industries (AlPac) has adopted adaptive management as principle for guiding operations in its large Forest Management Area in Alberta.

This introductory guide is intended to promote and assist with the application of adaptive management to a range of forest management issues in BC.

> Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form–"active" adaptive management–employs management programs that are designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed."
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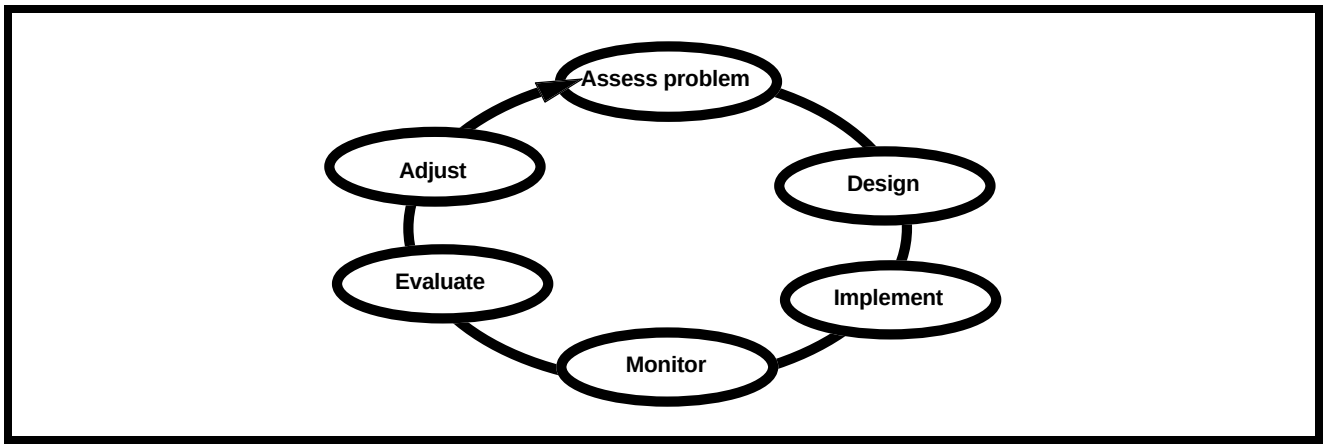
> *From* Nyberg, J.B. 1998. Statistics and the practice of adaptive management. Pages 1-7 *in* Statistical Methods for Adaptive Management Studies, V. Sit and B. Taylor, (editors). Land Manage. Handbook 42, B.C. Ministry of Forests, Victoria, BC.

Introduction

The purpose of this document is to assist those who wish to apply adaptive management, by providing a quick overview of the six main steps involved: 1) problem assessment, 2) design, 3) implementation, 4) monitoring, 5) evaluation, and 6) adjustment. The framework formed by these six steps is intended to encourage a thoughtful, disciplined approach to management, without constraining the creativity that is vital to dealing effectively with uncertainty and change. The details of how the steps are applied and the level of rigour used depends on the problem and on the imagination of participants. This guide is intended to provide direction, stimulate thought and augment discussions with resource people; it is not a detailed "how-to" manual. Nor is it a comprehensive discussion of adaptive management; those who want more background information can refer to the key references cited at the end of this document.

The six main steps in adaptive management are shown in Figure 1. Step 1 (**problem assessment**) is often done in one or more facilitated workshops. Participants define the scope of the management problem, synthesize existing knowledge about the system, and explore the potential outcomes of alternative management actions. Explicit forecasts are made about outcomes, in order to assess which actions are most likely to meet management objectives. During this exploration and forecasting process, key gaps in understanding of the system (i.e., those that limit the ability to predict outcomes) are identified. Step 2 (**design**) involves designing a management plan and monitoring program that will provide reliable feedback about the effectiveness of the chosen actions. Ideally, the plan should also be designed to yield information that will fill the key gaps in understanding identified in Step 1. It is useful to evaluate one or more proposed plans or designs, on the basis of costs, risks, informativeness and ability to meet management objectives. In Step 3 (**implementation**), the plan is put into practice. In Step 4 (**monitoring**), indicators are monitored to determine how effective actions are in meeting management objectives, and to test the hypothesised relationships that formed the basis for the forecasts. Step 5 (**evaluation**) involves comparing the actual outcomes to forecasts and interpreting the reasons underlying any differences. In Step 6 **(adjustment)**, practices, objectives, and the models used to make forecasts are adjusted to reflect new understanding. Understanding gained in the each of these six steps may lead to reassessment of the problem, new questions, and new options to try in a continual cycle of improvement.

FRAMEWORK FOR ADAPTIVE MANAGEMENT



In reality, some of the steps outlined will overlap; some will have to be revisited; some may be better done in more detail than others. All steps should be planned in advance, though it may be necessary to modify them later. All six steps are essential to adaptive management: omission of one or more will hamper the ability to learn from management actions. In addition, documenting the key elements of each step, and communicating results are crucial to building a "legacy of knowledge", especially for projects that extend over a long time.

This guide summarizes the key points to consider in each step and provides a checklist for quick reference. We have also included suggestions for creating the conditions that will facilitate long-term learning by individuals and their agencies, companies or communities. Some potential barriers to adaptive management, and suggestions for overcoming them, are noted in Appendix 2.

Learning how to do adaptive management is itself an adaptive process. Please let us know what works and what doesn't. We would appreciate feedback on the value of the outlined framework, how it could be improved, and how you applied it to different problems.

What are we trying to accomplish through adaptive management?

- find better ways of meeting goals
- identify key gaps in understanding
- improve understanding of ecosystem responses, thresholds and dynamics, in order to adapt practices to fit changing social values and ecological conditions
- gain reliable feedback about effectiveness of alternative policies/practices
- encourage innovation and learning
- pass on information and knowledge gained through experience
- foster an organizational culture that emphasizes learning and responsiveness
- in some cases, adaptive management may also help detect cumulative, long-term, large-scale, and emergent effects of actions

1. ASSESS PROBLEM

This step may be done in a workshop or series of workshops that bring together people with a variety of perspectives, skills, and areas of expertise. It is important to involve those who will implement, monitor and be affected by plans, as well as managers and scientists. For example, a workshop could bring together: forest managers, policy advisors, forest workers, scientists, First Nations, other forest users and people from local community groups. Simple problems will typically involve fewer people than complex problems.

For complex or contentious issues, it may be valuable to bring in 1-2 outside facilitators who, between them, speak the language of the relevant disciplines, are skilled at managing people, bring a systems perspective to issues, and are unbiased about the outcome. Facilitators should be involved early in the process and can help with both workshop preparation and follow-up.

In the workshop, participants first synthesize existing knowledge by developing a model of the system, and then use the model to explore different management options. For simple problems, the model may be a simple diagram or graph. For more complex problems (e.g., those where actions are projected over time and space), a computer simulation model is valuable. In some cases, it may be possible to modify an existing model. The steps outlined below are applicable regardless of the type of model used.

Although the key points below are presented in a numbered sequence, keep in mind that problem assessment is an iterative process. Be willing to return to earlier steps if necessary. For example, the exercise of exploring the effects of management alternatives may suggest new objectives, different management alternatives, or even that the problem should be addressed at a different spatial or temporal scale.

The elements of an assessment workshop are described in more detail in Appendix 1.

1.1 Define scope of management problem.

- Define spatial scale, temporal scale, and range of factors (i.e., values) to be considered.
- Define sensitivity of resource values (e.g., consider risk of damage).
- Consider aspects of the system that affect indicators or that are likely affected by management actions.
- Avoid defining problem in terms of preconceived solutions, since this would limit the development of imaginative alternatives.
- Consider long-term, cumulative and large-scale effects of management actions.

1.2 Define measurable management objectives and list potential management actions.

1.3 Identify key indicators for each objective.

- Indicators are measurable attributes of system behaviour that allow you to weigh management options and, eventually, assess outcomes.
- Select indicators that are relevant to objectives and responsive to management actions.

- Take into account the cost and practicality of measuring each indicator.
- Select some indicators that respond in the short term, some in the medium term, and some in the long term. Select indicators that respond at different spatial scales (e.g., site, landscape, region).

1.4 Explore effects of alternative actions on indicators.

- Develop a conceptual model of the system: outline linkages and describe the functional relationships between actions and indicators (e.g., using box-and-arrow diagrams, graphs, equations).
- If warranted, modify an existing simulation model or build a new one to represent the conceptual model. Simulation models are particularly valuable for projecting changes over time and space and assessing the integrated consequences of a suite of actions.
- Use the model (whether it is a simulation model or conceptual model) to explore the effects of alternative actions.

1.5 Make explicit forecasts about response of indicators to alternative management actions.

- Forecasts can be based on outputs from simulation models or, for simple problems, on the graphs or diagrams used to describe the relationships between actions and indicators.

1.6 Identify and assess key gaps in understanding (key uncertainties).

- Through exploring alternatives and forecasting responses, key gaps in understanding of the system will emerge. Express these key uncertainties as alternative hypotheses of system function. Hypotheses can be expressed as simple graphs, or where appropriate simulation models exist, as functional relationships or sets of model parameters.
- Consider the relationship between action(s) and indicators over a range of conditions (i.e., how will an indicator respond to different degrees of a treatment?).
- Assess the sensitivity of forecasts and management choices to alternative hypotheses. If different hypotheses lead to different forecasts or management choices, then it is worthwhile designing a management experiment that will discriminate between them[1]. (In modelling, this step is commonly referred to as "sensitivity analysis" because it involves assessing how sensitive model outputs are to different model assumptions or inputs).

Helpful tools & techniques

- AEAM workshops (see Appendix 1)
- conceptual models (e.g., box and arrow diagrams of potential impact pathways)
- simulation models

[1]Understanding of complex and dynamic ecological systems will always be incomplete. However, not all gaps in understanding necessarily need to be filled in order to decide between alternative management actions. For example, where different assumptions lead to the same forecast, or to the same choice of management action, there is no need to resolve the uncertainty about which assumption is "correct".

2. DESIGN MANAGEMENT PLAN

The purpose of this step is to design a management plan and monitoring program that are informative and provide reliable feedback. The most informative plans are those that are deliberately designed as management experiments, to discriminate between the alternative hypotheses formulated in Step 1. Typically, this involves comparing a range of management actions. This approach is referred to as "active adaptive management". The alternative, referred to as "passive adaptive management", is to assume that the most plausible hypothesis is true, and then implement the action or set of actions that the model forecasts will have the best outcome.

Active adaptive management usually provides feedback that is more reliable and less ambiguous than passive adaptive management. However, passive adaptive management may be the best (or only) alternative where:

- it is impossible or impractical to design a powerful experiment;
- the ecological costs of testing a range of actions is unacceptably high;
- there is a high level of certainty and agreement about which hypothesis is true, and thus which action is best;
- past actions or natural disturbances provide reliable information about response over a range of conditions.

Often, it is worthwhile evaluating several designs, one of which may be a "passive" design. In some cases it may be valuable to test actions in a pilot project before testing them at a larger scale, in order to narrow the range of plausible actions, and refine methodologies. In situations or areas where the risk of damage is high and irreversible, Steps 1 and 2 may lead to the decision to postpone any management intervention until research and trials in less vulnerable areas provide more information.

At this stage it is also important to plan - at least in a preliminary way - how the data will be managed and analysed; how actions, objectives, and models will be adjusted; and how information will be communicated.

2.1 Design management plan and monitoring program.

- Consider a number of management options, for example: a passive approach, where one action is implemented; an active approach, where several alternatives are compared; or testing a range of options at a pilot scale, before testing one or more at a larger scale.
- Ideally, a well-designed management experiment should include controls; replication of treatments in space and time; allocation of treatments to control for bias and environmental gradients, and to ensure statistical independence; and evaluation of confidence levels and power. Researchers and statisticians can provide valuable assistance in designing management experiments.
- If necessary, consider how and when to relax some of the design principles; note the consequences this will have for how the results are interpreted, and for the value of the resulting information.

2.2 Evaluate management options/alternative designs, and choose one to implement.

- Evaluate the proposed plan or plans, on the basis of ability to meet long term objectives, ecological and economic costs, risk of negative outcomes, and ability to fill key gaps in understanding. Decide which proposed plan to implement.

2.3 Design monitoring protocol.

- Specify:
  - the type and amount of baseline (pretreatment) data required;
  - frequency, timing, and duration of monitoring;
  - indicators to be monitored at each interval;
  - appropriate spatial scales for monitoring different indicators;
  - who is responsible for undertaking different aspects of monitoring.

2.4 Plan data management and analysis.

- Specify method(s) that will be used to analyse data.
- Set up system for managing data over the long term (e.g., storage, analysis, access).
- Agree on who will interpret data and who will have access to it.

2.5 State how management actions or objectives will be adjusted.

- Identify *who* needs *what* information *when* in order to make timely changes.
- Define the intensity and degree of response in an indicator that will trigger a change in management actions or objectives.
- Adjustments should reflect the trade-off between the costs of acting if preliminary results later prove to be incorrect, and the costs of *not* acting if they later prove to be correct.

2.6 Set up system to communicate results and information.

Helpful tools & techniques

- quantitative decision analysis (see Keeney, 1982; McAllister and Peterman, 1992)
- project plan that documents uncertainties, design, and other parts of Steps 1 and 2

3. IMPLEMENT MANAGEMENT PLAN

3.1 Follow the plan!

- In some circumstances, it may be necessary to deviate from the original plan: decide when and what type of deviations are acceptable. Ensure that these circumstances are clear and accepted by all partners. Otherwise, the "tyranny of small decisions" may eventually invalidate the plan or lead to loss of confidence and support by partners.

3.2 Monitor implementation and document any deviations from plan.

4. MONITOR

Monitoring is often neglected in conventional approaches to management, yet it is critical to improvement. Monitoring allows you to assess how actions *actually* affect indicators. This information then allows you to evaluate the effectiveness of alternative actions, adjust models (i.e., hypotheses) of how the system functions, and take appropriate corrective action. Monitoring can also determine if actions were implemented as planned, and may detect "surprising" events.

4.1 Monitor for:

- implementation or compliance (did we do what we planned?);
- effectiveness (did the plan meet objectives?);
- validation of model parameters and relationships (which hypothesis is correct?);

4.2 Follow the monitoring protocol designed in Step 2.

Helpful tools and techniques

- consider using volunteers for some types of monitoring
- consider developing new, innovative and inexpensive monitoring techniques (e.g., videos or photographs of sites)

5. EVALUATE

In this step, data are analysed and actual results are compared to forecasts made in Step 1. The evaluation should explain *why* results occurred and include recommendations for future action. Outcomes can be the result of the management action, confounding factors not under your control, or both. The strength of your inferences (e.g., that the action lead to the outcome) depends on the design of the management experiment and monitoring program. Better designs permit stronger inferences. Negative or unexpected outcomes can be as informative as positive, predicted outcomes.

Results, whether expected or unexpected, must be documented and communicated, so that knowledge and experience are passed on to others facing similar problems.

5.1 Compare actual outcomes to forecasts made in Step 1.

- Evaluate the reasons underlying any differences between actual and forecasted outcomes. Were the objectives met? If not, why not?
- Evaluate to what degree tested hypotheses are supported by the results.

5.2 Document results and communicate them to others facing similar management issues.

6. ADJUST

Information must be used in order to have value. Information gained through the preceding five steps should be used to verify or update the models used to make the initial forecasts, and adjust management actions as necessary. Objectives should be reviewed and adjusted to ensure that they remain consistent with overall goals and values.

In order to facilitate change, participants should consider at the outset (i.e., in Step 2) how actions might be adjusted. However, results are rarely as clear as anticipated, and thus adjustments are rarely as simple as those proposed initially. In addition, management experiments may yield some useful information that was not anticipated. Well-defined feedback loops are intended to ensure that information is used promptly and appropriately; they are not meant to be rigid rules that frustrate adaptation.

Often, new information will suggest new management solutions, or new questions to answer...leading to another cycle of assessment, design, implementation, monitoring and evaluation.

6.1 Identify where uncertainties have been reduced, and where they remain unresolved.

6.2 Adjust the model used to forecast outcomes (Step 1) so that it reflects the hypothesis supported by results.

6.3 Adjust subsequent management decisions and policies, and reevaluate objectives, as necessary.

- In deciding what adjustments to make, consider the reasons underlying differences between expected and actual outcomes (Step 5).
- Future actions should be based on which hypothesis of system function was supported by the results.

6.4 Make new predictions, design new management experiments, test new options.

- i.e., return to step 1 or 2
- In future management experiments, address unresolved or newly-identified uncertainties that affect predicted outcomes and decisions about which actions to implement.

Documenting plans and communicating results

Documenting plans and communicating results are crucial elements of adaptive management. The impact of many management activities can be assessed reliably only over the long term. All aspects of adaptive management, including funding, project co-ordination, data handling, and dissemination of information, must be designed to accommodate the potentially long time frame.

1. Document all major steps in the process including:

- functional relationships, models, key uncertainties;
- reasoning behind the choice of management plan, monitoring program and expected outcomes;
- methods, sites, treatments;
- participants and their roles and responsibilities.

2. Ensure that such information is accessible over the long term, and in the event of turnover in participants.

3. Define who is responsible for co-ordinating and for carrying out each task.

4. Set time lines for carrying out each task or part of project.

5. Distribute interim and final results.

- A number of avenues can be used to communicate results, including written progress and final reports, presentations, seminars, field trips, informal discussions, posters.
- In communicating the results, specify which uncertainties have been reduced, and how this affects understanding of the system and future management actions.

Creating success: what you can do to facilitate learning

Project leaders play a crucial leadership role in encouraging the conditions that facilitate adaptive management. In particular, institutional environment and individual attitudes are as critical to effective adaptive management and learning as the actual steps followed. There is an extensive body of literature that discusses "organizational learning"; we encourage you to refer to some of the references listed on page 18. Below are some specific recommendations for creating success in adaptive management.

1. ***Create an atmosphere and promote an attitude that is conducive to long-term learning - where:***
   - mistakes are recognized as the price of innovation and are treated as opportunities to learn;
   - the desire (incentive) to improve is greater than the fear of failure;
   - there is more patience and less demand for quick fixes;
   - people are explicitly rewarded for innovation and learning (i.e., in performance evaluations).

2. ***Ensure that all participants have a clear, consistent understanding of adaptive management.***

3. ***Build contingency plans into project to deal with:***
   - potentially negative outcomes of some treatments;
   - unanticipated and uncontrollable events that compromise design (e.g., wildfires that destroy replicates);
   - interruptions in funding;
   - external pressures to alter projects.

4. ***Anticipate potential barriers and develop strategies for overcoming or minimizing them.***
   - See Appendix 2.

A Final Comment

In using this introductory guide, keep in mind that adaptive management is like painting: knowing the steps is important, but it isn't enough to create great art. Potential project leaders and participants are encouraged to use other resources, including those offered by the BC Forest Service Adaptive Forest Management initiative. We must learn how to do adaptive management by doing it.

APPENDIX 1

Adaptive Environmental Assessment and Management (AEAM) Workshops

AEAM is a process where participants with a diversity of skills and expertise are brought together in a workshop or series of workshops to assess a management problem and explore management options. Usually, participants work with modellers to develop a computer simulation model that they then use to explore various "what if..?" scenarios and evaluate potential outcomes of different management actions. In addition, significant benefits are derived from the *process* of building the model. The workshops are intended to encourage debate about system response to management actions and to stimulate a creative search for new solutions, rather than build consensus around a single solution. In some cases, the scope of the problem and the options explored will be bounded by prior decisions about land-use (for example, those defined in Land and Resource Management Plans, or other regional or local land-use plans).

The AEAM workshops are valuable for:

- building a common understanding of the problem;
- synthesizing existing knowledge;
- highlighting key uncertainties and clarifying assumptions;
- stimulating creativity and generating new management options.

The model allows participants to:

- project potential effects over time and space;
- forecast potential effects of cumulative management actions; and it
- provides a consistent basis for participants to discuss and evaluate management options.

AEAM workshops typically involve the steps outlined below, although they can be tailored to suit the management problem and available budget. In some cases these steps will be done in a single workshop, over one or several days; in other cases, they may be done in a series of workshops, with some participants working on particular aspects of the problem in between. Work is done in both plenary sessions and sub-groups.

While model-building is valuable for focusing discussion, workshops where time or budget constraints preclude computer modelling can still be useful. The development of conceptual models is itself a very worthwhile exercise. To maximize the value of the workshop, objectives and expectations must be clearly understood by all participants, including the modellers and facilitators.

AEAM is an iterative process - later steps may lead to reevaluation and reiteration of earlier steps. For example, it may be useful to model the problem at several different spatial scales. Similarly, exploring the effects of management options may suggest alterations to model parameters or relationships, or new options to try.

Steps that were outlined in section 1 (Assessing Problem) are noted.

Prior to the first workshop, typically in a meeting between the facilitator(s) and the project leader(s):

1. Identify key participants.

The first workshop may involve 20-30 people, including:

- modellers/facilitators
- forest managers and planners
- "knowledge experts" from a range of disciplines (e.g., hydrologists, wildlife biologists, fisheries biologists, social scientists, etc.)
- policy-makers
- forest workers
- people with local knowledge
- other stakeholders

Participants can be drawn from government agencies, industry, community groups, environmental organizations, First Nations or other groups with expertise to contribute or who will be affected by management decisions. The mix and quality of participants is critical to workshop success. Participants should not only have relevant expertise, but should also be creative, innovative thinkers.

2. Define the initial scope of the problem and key problem features.
(e.g., spatial and temporal scale, range of factors to consider, key indicators)

- This can help keep the workshop on track.
- For some problems it also may be useful to summarize existing, accepted knowledge about the system. This can "jump start" the process and minimize time spent on issues about which their is already general agreement.
- It is critical that participants not feel constrained by this initial problem scoping; leaders/facilitators must be prepared to alter or abandon any boundaries or framework developed prior to the workshop.
- In some cases, the scope of the problem will be influenced by land-use decisions made by other bodies (e.g., LRMPs). Decisions made by AEAM participants should not conflict with or supersede those made by other decision-making bodies.

During the workshop(s):

In the group as a whole:

3. Define scope of problem (see section 1).

- The participants in the workshop should have the opportunity to revise the scope defined by the facilitator(s) and project leader(s) prior to the workshop, to ensure that issues of concern are addressed. This is the first step in building a common understanding of the problem.

4. Define measurable management objectives (see section 1)

5. Identify key indicators for each objective (see section 1).

6. Identify possible management actions (see section 1).

Actions and indicators are then grouped into logical sub-groups (e.g., based on theme or scale). Participants are assigned to these sub-groups based the knowledge and skills they can contribute. In each sub-group:

***7. Draw impact hypothesis diagrams** (for given group of actions and indicators).*

- These "box and arrow" diagrams outline the linkages between management actions and indicators and represent a synthesis of existing knowledge on each subsystem.
- Impact hypothesis diagrams are not intended to show detailed links between all components of the system - only those that affect management outcomes/decisions.

8. Identify and assess key information gaps (see section 1).

- Evaluate links in impact hypothesis diagram, considering: quality of existing information, level of influence on outcome, feasibility of filling information gap. One suggested system for assessing alternative hypotheses is:
    1. unlikely, not worth testing
    2. already tested
    3. possible, too difficult to test
    4. uncertain, research needed
    5. likely, worth testing

Work in sub-groups alternates with discussion in plenary sessions. This ensures that the sub-groups understand and have a chance to comment on each other's assumptions, and ensures that the diagrams form a coherent whole. "Outputs" of one diagram will be "inputs" to another.

9. Modify an existing simulation model or develop a new one.

- In some cases there may be an existing model that captures the relevant pathways and conceptual model expressed in step 7 above. If so, this model can be used to explore alternative actions. If a suitable model is not available, develop a new one based on the impact hypothesis diagrams.
- While a crude model can be developed in the workshop, typically it will have to be refined before it can be used for exploring scenarios and forecasting outcomes.

10. Test and validate the model; do sensitivity analysis on model parameters.

- Test model to determine how sensitive outcomes are to variations in model parameters.
- Sensitivity analysis helps narrow in on those areas of uncertainty that most affect management outcomes.

11. Explore alternative scenarios/management options.

- Develop a range of plausible management options.
- Use the model to explore the effects of these options on indicators.
- This "gaming" with the model is usually done in the group as a whole.

12. Make explicit predictions about response of indicators (see section 1).

A reminder: AEAM is an iterative process- not sequential as summarized above. The model will be continuously refined and tested, new options developed and explored, and new predictions made.

The AEAM process should provide participants with:

- a common understanding of the problem;
- a list of key indicators;
- documented assumptions about how the system functions, how variables respond (i.e., the model);
- predictions about the effects of alternative management actions;
- a list of key uncertainties in model parameters and relationships (i.e., those that have most influence on outcomes);
- a list of plausible alternative hypotheses that should be tested, in order to improve understanding of system behaviour and its representation in the model, and thus improve management decisions;
- an idea of what "probing actions" can be taken to test these alternative hypotheses.

APPENDIX 2

What are likely to be the main barriers to adaptive management?

An important component of any adaptive management plan will be to anticipate potential problems and devise strategies for avoiding, minimizing or overcoming them. In the Table below we list some potential barriers, the steps they will likely affect, and some potential solutions. To some extent the barriers that arise will depend on the characteristics (e.g., scale, complexity) of the management issue. It is also important to note that some of these barrier are not unique to adaptive management.

Potential Barriers	Steps affected	Comments/Potential solutions
1. **additional costs** (e.g., for model development, layout, monitoring)	all	• identify designs and monitoring schemes that offer best trade-off between cost and effectiveness (i.e., using decision analysis) • compare potential cost: benefit of adaptive management to that of conventional management (i.e., assess the potential long-term cost of implementing "wrong" or ineffective practices) • consider using volunteers for some aspects of monitoring and layout • develop cheaper measurement techniques that still provide reliable information • identify cost-sharing partnerships
2. **designing powerful experiments** (potential constraints on design include: long response times, large spatial scales, high variability between sites, high variability in measurements)	2, 5	• use alternative methods of statistical analysis (e.g., Bayesian statistics) • draw on other sources of knowledge to help interpret results (e.g., retrospective studies, descriptive studies, process research, local knowledge) • designs that are less than ideal may still provide useful information - consider consequences of relaxing design rules and accepting lower levels of precision, confidence in results • lack of powerful design does not preclude adaptive management - it just makes interpretation of results more difficult
3. **reluctance to "experiment" with high value, threatened ecosystems**	2	• use quantitative methods of risk analysis to assess and compare alternative designs/options • passive approaches may be less risky than active approaches *in some circumstances* • test risky actions in small, pilot studies or in "less valuable" areas before applying them more widely • design contingency plans (e.g., halt or adjust treatments when indicators reach predetermined "thresholds of acceptable change") • monitor some indicators that respond quickly, or that are particularly sensitive to change (e.g., behavioural changes may precede population changes) • recognize that the risk of managing in continued ignorance is also high

4. **maintaining continuity of funding, support, staff over the long term** (despite changes in political and economic climates)	all, especially 4,5	• establish realistic expectations (so the project isn't prematurely judged to have "failed") • document assumptions, objectives, treatments, sites etc., and ensure that information is accessible (e.g., sites, treatments, status could be mapped on GIS map layers and stored electronically and as hard copy maps) • document and communicate interim results and knowledge gains • write formal plan that: states long-term schedule of treatments, monitoring, evaluation; assigns responsibility for tasks to specific individuals or positions • generate local support and sense of ownership in project beyond government agencies (e.g., by incorporating into regional plans, through public education and involvement) • have outgoing staff train incoming staff (overlap "employment windows") • if possible, design plans to weather interruptions in funding (so that you can still get some information if funding is reduced) • ensure funding is reserved at the time of initial harvest, perhaps as a bond posted as a condition of harvesting
5. **logistics of collecting, storing, analyzing data so that it is accessible over the long term**	4,5	• develop explicit, written plan for handling data (e.g., who is responsible for tasks, storage format, access) • a well-designed, focused monitoring program will minimize the amount of data that is generated • integrate data from adaptive management with other standard databases
6. **regulatory and institutional inflexibility** (real or perceived)	1, 2, 5	• for some issues, the FPC provides enough flexibility to test a range of treatments • the FPC states *minimum* standards-and does not prevent testing of practices that exceed them • analysis of past management actions will often provide information on response at one end of a range
7. **"institutional inertia"** (reluctance to change practices, objectives or opinions; barriers to quick response; prior commitment to certain course of action)	5	• get commitment from all participants, at outset • ensure good, ongoing communication between those who make decisions and those who implement and evaluate them • delegate decision-making authority to those as close to the ground as possible (but with checks and balances) • get agreement at outset on how potential results will change objectives, or practices • sense of ownership in project will enhance willingness to change on basis of results
8. **pressure to alter plans or poor understanding of how to implement plans**	3	• involve range of stakeholders, agencies from the outset • involve operations staff or contractors responsible for implementing plans in assessment and design phases • anticipate potential pressures that may arise to alter plans and agree on response; will it compromise the project?
9. **fear of admitting uncertainty, making mistakes, trying new solutions**	all	• define “learning how to manage better” as one management objective • build public trust through education, public involvement in process • reward learning and innovation in performance evaluations

10. **unclear, inconsistent definition of adaptive management and how it should carried out**	all, especially 1	• define adaptive management clearly and consistently at the outset • reinforce and repeat the definition throughout the process • correct misinterpretations when they arise

APPENDIX 3

Definitions

Indicators: - measures of system behaviour in terms of meaningful and perceptible attributes
- what do we really need to know in order to make a decision?
- what do we need to measure to determine if management objectives have been met?
    - allow us to assess alternatives, weigh options

Actions: - activities to be considered in assessment of alternatives

Hypotheses: - predictions about how one or more indicators will respond to management actions
- alternative explanations for the mechanisms that underlie observed responses
- the most useful hypotheses state the *degree* of response, or describe the response over a *range* of conditions; hypotheses that state only whether an indicator will or won't respond to a treatment are less useful for deciding between alternative courses of action, or making informed trade-offs

Passive adaptive management:

- managers select the "best" management option, assuming that the model on which the predictions are based is correct.

Active adaptive management:

- managers design practices so as to discriminate between alternative models, and thus reveal the "best" management action. This sometimes involves testing practices that differ from "normal", in order to determine how indicators will respond over a range of conditions.

Both passive and active adaptive management require careful implementation, monitoring, evaluation of results, and adjustment of objectives and practices. Active adaptive management usually allows more reliable interpretation of results, and leads to more rapid learning.

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Steps in adaptive management

1. Assess Problem

- Define scope of management problem.
- Define measurable management objectives.
- Identify key indicators for each objective.
- Explore effects of alternative actions on indicators
- Make explicit forecasts about responses of indicators to management actions
- Identify and assess key gaps in understanding.

2. Design (management plan)

- Design management plan that will provide reliable feedback and fill gaps in understanding.
- Evaluate management options/alternative designs, and choose one to implement.
- Design monitoring protocol.
- Plan data management and analysis.
- State how management actions or objectives will be adjusted.
- Set up system to communicate results and information.

3. Implement

- Follow the plan!
- Monitor implementation and document any deviations from plan.

4. Monitor

- Monitor for: implementation, effectiveness, validation and surprises.
- Follow the monitoring protocol designed in Step 2.

5. Evaluate/ Adjust

- Compare actual outcomes to forecasts made in Step 1.
- Document results and communicate them to others facing similar management issues.

6. Adjust

- Identify where uncertainties have been reduces and where they remain unresolved.
- Adjust the model used to forecast outcomes, so that it reflects the hypothesis supported by results.
- Adjust management actions and reevaluate objectives as necessary.
- Make new predictions, design new management experiments, test new options...repeat cycle.

Document plans and communicate results

- Document all major steps in the process.
- Ensure that information is accessible over the long term.
- Define who is responsible for co-ordinating and for carrying out each task.
- Set time lines for carrying out each task or part of project.
- Distribute interim an final results.

Create Success

- Create an atmosphere and promote an attitude that is conducive to long-term learning.
- Ensure that all participants have a clear, consistent understanding of adaptive management.
- Build contingency plans into project.
- Anticipate potential barriers and develop strategies for overcoming or minimizing them.